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Highly Efficient Yb-doped Laser Fiber Synthesized by Vapor-phase Doping Technique

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1. Introduction

High power fiber lasers have become an area of active interest for several industrial, medical and strategic applications. The key component of a high power fiber laser module operating at around 1 µm is Ytterbium (Yb) doped optical fiber of large mode area (LMA) structure with high RE concentration and uniform dopant distribution [1]. In this context, vapor phase technique based on high temperature sublimation of RE chelate compounds has shown high potential compared to conventional solution doping method. Recently, high success has been reported in producing good quality fibers employing this technique [2]. In this paper, the performance of Yb–doped fibers fabricated through vapor phase doping technique is reported.

2. Experimental

The core of the preforms was formed by depositing sintered layers of silica–alumina–ytterbium oxide (SiO_2–Al_2O_3–Yb_2O_3) nano-particles using a specially constructed MCVD system containing High Temperature Vapor Delivery Unit with sublimators, unique rotary seal and ribbon burners. The solid Yb-chelate compound [$Yb(thd)_3$] and anhydrous $AlCl_3$ were heated in the respective sublimators at high temperature and the generated vapors were transported to the reaction zone by using Helium carrier gas. The advantage of the method lies in formation of Al_2O_3 and Yb_2O_3 in vapor phase along with SiO_2 and simultaneously deposition of oxide nano-particles in continuous approach which enhances homogenous distribution of dopants in the glass network. Multiple core layers were deposited in a reproducible "in-situ" manner through well controlled precursor vapor generation for fabricating large core fibers which was followed by stepwise collapsing at high temperature. The conditions were optimized to draw double D – shaped low index acrylate resin coated fibers which were then characterized to assess core diameter, numerical aperture (NA), dopants distribution, background loss, photodarkening induced loss (PDIL) and finally, the lasing properties by using a free–space coupled Fabry–Perot setup.

3. Results

The core diameter of the fibers was tuned in the range of 14.5 – 24.2 µm with respect to an overall diameter of 200 µm and NA in the range of 0.08-0.11, for achieving single mode or few mode operations at laser wavelength of around 1 µm in the resulting fiber. The background loss of the fibers is in the range of 16–20 dB/km at 1200 nm and the OH^- content in the set of fibers was restricted below 2.5 ppm without using Cl_2. The doping levels of the core material are in the range of 0.2–0.8 mol% for Yb_2O_3 and 1.0–2.4 mol% for Al_2O_3 as detected by electron microprobe analysis (EMA). The EMA curves show uniform distribution of Yb_2O_3 and Al_2O_3 in the core region with negligible center dip. The fibers are also devoid of any "star-like" imperfection at the core-clad boundary, which is generally formed due to viscosity mismatch in conventional method.

The fibers show comparatively low PDIL at 635 nm and attain saturation around 30 dB/m after 4 hours. In laser experiment, 90% of the pump light was absorbed for a length of 2.5 m fiber. A linear increase of the laser output power up to 105 W with a slope efficiency of 77 % has been achieved at 1060 nm emission wavelength as shown in Fig. 1. The result shows that there is no roll-over of the output power which indicates laser power could be increased further with available pump power. The laser was in operation for three hours continuously without any noticeable degradation in output power.

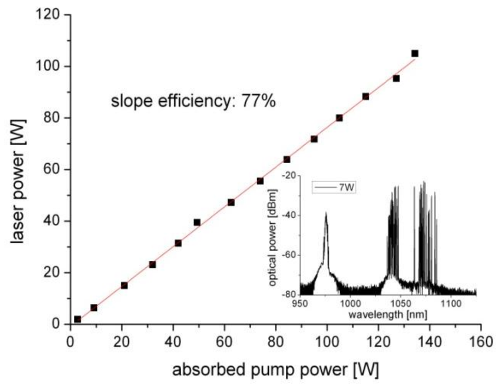

Fig.1. Laser characteristics and transmission spectrum (inset) of fabricated Yb-doped fiber

4. Conclusions

We report the operational characteristics of Yb-doped laser fibers fabricated through vapor phase doping technique. Fabricated fibers exhibited low attenuation with excellent slope efficiency and a broad emission spectrum. This progress gives rise to the possibility of designing highly Yb-doped active fibers with large core clad ratio for next generation high power laser devices.

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References

[1] Y Jeong et. al., Opt. Express **12** (2004) 6088.
[2] M Saha et. al., Photonics Technol. Lett. **26** (2014) 58.